Abstract of the Ph. D. Thesis

Title: Group III-nitride Epi and Nanostructures on Si (111) by Molecular Beam Epitaxy

The present work has been focused on the growth of Group III-nitride epitaxial layers and nanostructures on Si (111) substrates by plasma-assisted molecular beam epitaxy. Silicon is regarded as a promising substrate for III-nitrides, since it is available in large quantity, at low cost and compatible to microelectronics device processing. However, three-dimensional island growth is unavoidable for the direct growth of GaN on Si (111) because of the extreme lattice and thermal expansion coefficient mismatch. To overcome these difficulties, by introducing β-Si_3N_4 buffer layer, the yellow luminescence free GaN can be grow on Si (111) substrate. The overall research work carried out in the present study comprises of five main parts. In the first part, high quality, crack free and smooth surface of GaN and InN epilayers were grown on Si(111) substrate using the substrate nitridation process. Crystalline quality and surface roughness of the GaN and InN layers are extremely sensitive to nitridation conditions such as nitridation temperature and time. Raman and PL studies indicate that the GaN film obtained by the nitridation sequences has less tensile stress and optically good. The optical band gaps of InN are obtained between ~0.73 to 0.78 eV and the blueshift of absorption edge can be induced by background electron concentration. The higher electron concentration brings in the larger blueshift, due to a possible Burstein–Moss effect. InN epilayers were also grown on GaN/Si(111) substrate by varying the growth parameters such as indium flux, substrate temperature and RF power.

In the second part, InGaN/Si, GaN/Si_3N_4/*n*-Si and InN/Si_3N_4/*n*-Si heterostructures were fabricated and temperature dependent electrical transport behaviors were studied. Current density-voltage plots (*J*-*V*-*T*) of InGaN/Si heterostructure revealed that the ideality factor and Schottky barrier height are temperature dependent and the incorrect values of the Richardson's constant produced, suggests an inhomogeneous barrier at the heterostructure interface. The higher value of the ideality factor compared to the ideal value and its temperature dependence suggest that the current transport is primarily dominated by thermionic field emission rather than thermionic emission. The valence band offset of GaN/β-Si_3N_4/Si and InGaN/Si heterojunctions were determined by X-ray photoemission spectroscopy. InN QDs on Si(111) substrate by droplet epitaxy and S-K growth method were grown in the third part. Single-crystalline structure of InN QDs (droplet epitaxy) was verified by TEM and the chemical bonding configurations of InN QDs were examined by XPS. The interdigitated electrode pattern was created and (*I*-*V*) characteristics of InN QDs were studied in a metal–semiconductor–metal configuration in the temperature range of 80–300 K. The *I*-*V* characteristics of lateral grown InN QDs were explained by using the trap model. A systematic manipulation of the morphology, optical emission and structural properties of InN/Si (111) QDs (S-K method) is demonstrated by changing the growth kinetics parameters such as flux rate and growth time. The growth kinetics of the QDs has been studied through the scaling method and observed that the distribution of dot sizes, for samples grown under varying conditions, has followed the scaling function.

In the fourth part, InN nanorods (NRs) were grown on Si(111) and current transport properties of NRs/Si heterojunctions were studied. The rapid rise and decay of infrared on/off characteristics of InN NRs/Si heterojunction indicate that the device is highly sensitive to the IR light. Self-aligned GaN nanodots were grown on semi-insulating Si(111) substrate. The interdigitated electrode pattern was created on nanodots using photolithography and dark as well as UV photocurrent were studied. Surface band gaps of InN QDs were estimated from scanning tunneling spectroscopy (STS) *I*-*V* curves in the last part. It is found that band gap is strongly dependent on the size of InN QDs. The observed size-dependent STS band gap energy blueshifts as the QD's diameter or height was reduced.